Authors responses to review 2

In this document, we have repeated the reviewers comments in the *italics* and our responses are in the standard font.

The manuscript by Raznjevic et al. focuses on the application of LES model to understand point-source methane plume behavior. It's a timely and welcomed addition that enriches our understanding of LES model in real world dispersion study. The observation data is collected near an oil well during the ROMEO campaign, and the boundary conditions in the LES model is derived from ERA5 data. The idea is interesting, and it should enrich our understanding of plume behavior. Because the LES model can provide much more details than filed observation and simple Gaussian model. However, the conclusions of this manuscript are mostly descriptive, and several statements are not thoroughly supported.
We would like to thank the reviewer on their kind words and the time they have invested in reading and evaluating our paper. We will try do address the comments they have to the best of our abilities so that we can clarify any statements that are not well supported and be more quantitative in our conclusions.

Specific comments:

1 Some basic information of the observation campaign is missing. In section 2.2, there are two basic measurement instruments: TILDAS for CH4 and GILL R3 for wind speed, TILDAS was placed at the top of the vehicle. I'm not sure if the observation data were collected when the vehicle was moving, or collected when the vehicle stopped at the observing spot. If the data were collected when the vehicle was moving, the uncertainty of the observation data is very large. The authors should provide the time series or the linearly interpolated observation data (I'm not sure if figure 6 shows the original observation data, it says CH4 measured over the read adjacent to the emitting oil-well.), including the location of the vehicle.
The TILDAS spectrometer was placed in the vehicle, with in inlet in the from at 3 m height. A GILL 3D Windmaster (sonic anemometer), was placed at a height on 180 cm, 25m from the source but free from obstructions for windspeed and wind directions measurements. The measurements took place while driving downwind of the oil well, to collect the plumes of the oil well and the N2O tracer. If needed, we can add as supporting information the recorded tract of the vehicle as it was measuring the plume.
Yes, the data shown on Fig. 6 is directly measured data, so no linear interpolation.

And if possible, the authors should provide some basic meteorology information, such as wind, temperature, relative humidity. Most of the meteorology information was from ERA5 data, which has a spatial resolution of 31km, and the study area is in vicinity of hills, the meteorological parameters are not homogeneous.
Windspeed and wind direction, as shown in Fig. 6 (b) and (c), were measured onsite with the anemometer. These local measurements are needed for the emission determination. Measurements took place at a sunny day without clouds. Meteorological information as temperature, pressure and relative humidity

are derived from ERA5, which is suitable spatial resolution for defining the stability class.

2 According to the authors, the study area is in vicinity of hills. The surrounding environments, such as topography and buildings, should be provided by the authors. Because the dispersion near the surface (the observation is about 3 m above ground level) was deeply affected by the surroundings. In some LES models, the topography options are available, for example PALM. If the topography options is available in MicroHH, the surrounding environments should be added into the model before simulation. And the simulated wind data should be improved.
Yes, the mountainous area started 5 - 10 km N-NW of the study area. The are itself was flat grassland with very little obstacles. The space between the oil well and the road on which the measurements were taken had no obstacles that could distort the plume. In our simulation there is no orography or any kind of obstacles because we were simulating dispersion on a 4.8 $\times$ 4.8 km area around the source that were just flat fields. However, the reviewer is right about including the orography to minimize the errors in the wind direction that we had in the first simulation (section 4.1.). For this particular case that would mean expanding the simulation domain far beyond the studied area to include the surrounding hills. This would have as a consequence a huge increase in the computing costs because the resolution would have to be kept same to what it is now to see the fine detail of the plume close to the source. Those kinds of simulations are unfeasible at the moment. We circumvented this problem by matching our simulated winds with the observed one in the second simulation since we did not expect huge orographic influence on the instantaneous wind, rather on timescales of an hour, as the hills were some distance away. The the problem with the domain size and required resolution is encountered in other models capable of performing the LES (such as PALM). The possible topographic forcings should be adapted in the boundary conditions, but here we encountered the problem of ERA5 resolution being too low to capture the local topography. We recognize this point has not been stressed enough in the motivation part of our paper, and we will add this discussion in the results section where the comparison of modeled and measured wind is being compared (section 4.1).

3 In figure 6, the authors have provide the time series of observed wind speed and wind direction data, compared with simulated values. It seems that the observed and simulated values are irrelevant. The authors said that was possible caused by influences from the local orography. In my opinion, the comparison is unreasonable, because the surface in ideal model is flat, while it's heterogeneous in real world. And the GILL R3 is mounted only 1.8 m above ground level which is totally influenced by the surrounding environments. If there is no other wind measurement, the validation of modeled meteorological conditions is unnecessary. Because the boundary condition in the LES model is derived from ERA5 data, and the modeled profiles show very good agreement with ERA5 profiles.
Yes, we mentioned the influence on the local orography on the wind, but since the first mountains were located 5 - 10 km N and NE from the site, we expected only the influence on longer period fluctuations. We refer to the paper of Nastrom et al. (1987, https://doi.org/10.1175/1520-0469(1987)044<3087:AIOTEO>2.0.CO;2) where they have shown that the mountains can have influence on atmospheric variability extending 4 to 80 km. This was added to the paper in the Result section.
The nudging towards the ERA5 profiles in our simulation was only weak. Our goal was to have a well developed turbulent boundary layer with only the mean characteristics constrained in the boundary conditions. For this reason it was important to verify with the measurements that a good wind profile was delivered by the model.
As mentioned above, the area around the oil well was flat grassland. No obstacles that could influence the wind or the plume were present. The land there, as anywhere, has some roughness to it (from the

grass for example) but this is calculated into our model. The LES in MicroHH uses a surface model that is constrained to rough surfaces and turbulent flows. The model computes the surface fluxes of the horizontal momentum components and the scalars using Monin–Obukhov similarity theory.

Technical corrections:
Figure1 Please add more information about the surrounding environments (such as google earth), the measurement (such as a photo of the vehicle).
Added both the Google Earth image of the oil well and the photo of the vehicle.

Line 93-111 The discussion of meteorological situation over the whole Europe is unnecessary. The low wind speeds during the campaign is enough for the explanation of local influence.
It is a bit superfluous have the pressure map over the whole Europe, we agree with that. We will shorten the discussion down only to the area above Romania and at the measurement site.

Line 111 The contribution of the large scale advection was ...
Fixed.

Line 121 What does B20 flasks means
B20 flasks are 20L cylinders; volume at 100bar = 2000L gas. This was added to the text.

Figure 2 Since you have an sonic anemometer (GILL R3), the observed sensible heat flux can be calculated.
Yes, this is true, we agree with the reviewer. We have added to here a figure showing the comparison of surface sensible heat flux from the ERA5 data and the 10 min averages that were available from the sonic anemometer. Both measured and fluxes from ERA5 show very similar values for the duration of measurements. Since the fluxes from the measurements were available for only fraction of the day, and we have used Fig. 2 to describe the meteorological conditions in the simulation, we have chosen to show only ERA5 values.

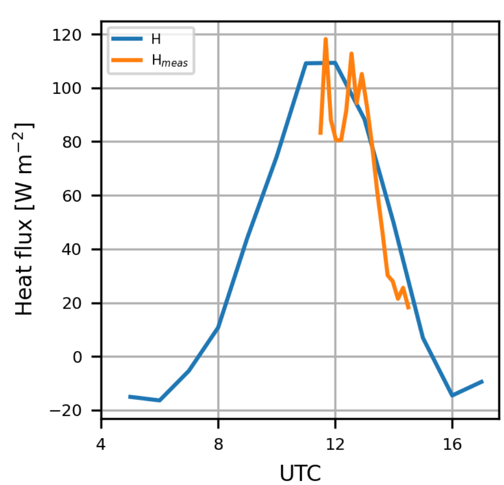

Figure 1: Sensible heat flux from ERA5 (hourly values) and calculated from the sonic data (10 min averages) at the location of the measurements.

Line 172 Since the study area is heterogeneous (hills), the roughness length should be much larger.
We hope this is clarified with the discussion above. But, again, the studied area was flat grassland. These roughness lengths correspond with that kind of terrain.

Line 250 Replace "Them" with "The".
Replaced.

Line 251-258 It can not be seen that the wind angle in the idealized simulation fluctuates comparable to the observations.
Standard deviations in wind direction are $\sigma_{WD,meas}$ = 16.9° for the measured wind and for the LES $\sigma_{WD,LES}$ = 18.6°, so they are quite similar. This has been added to the text.

Line 315 The boundary layer height (hBL) is determined by what ? The profile of potential temperature ? The profile of sensible heat flux ?
The boundary layer height has been calculated as a the maximum of domain- and time- averaged vertical profile of potential temperature gradient. This quantity is easily obtained from the MicroHH output. The explanation is added to the text.

Line 542 LES can not reproduce meteorological conditions. The meteorological conditions are boundary conditions.
LES has periodic boundary conditions on all variables, apart from the scalar that represents the plume. This means that all the momentum, heat and humidity that exits through the left boundary enters back into the simulation through the right. So in that sense there are no true boundary conditions in this simulation. The meteorological conditions were imposed by nudging the simulation towards them so the simulation does not drift too much from them. This is why we point out that LES was successful in reproducing the real meteorological conditions.